Guidebook to the Triassic Formations of the Colorado Plateau
in northern Arizona: Geology, Paleontology, and History.
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PETRIFIED FOREST NATIONAL PARK: A ROADLOG

WILLIAM G. PARKER

Division of Resource Management, Petrified Forest National Park, Box 2217, Petrified Forest, AZ 86028
William_Parker@nps.gov

INTRODUCTION

In 1906 Theodore Roosevelt established Petrified Forest National Park (PEFO) in northeastern Arizona to preserve the "remnants of the Mesozoic Forests." The park currently comprises 98,000 acres, although in 2004 Congress passed legislation that expands the administrative boundary, effectively adding more than 120,000 additional acres to the park (Fig. 1).

Two main geographical features exist within the park, Painted Desert Mesa and the "Chinle Escarpment." Painted Desert Mesa, a Tertiary volcanic remnant of the Mio-Pliocene Bidahochi Formation, forms the caprock above the Upper Triassic Chinle Formation and provides scenic vistas into a portion of the Painted Desert. The "Chinle Escarpment," an east-west trending series of buttes and mesas is made up primarily of Chinle Formation strata. The Puerco River and over eight miles of high desert prairie separates the "Chinle Escarpment" and Painted Desert Mesa. This separation has made it difficult to correlate stratigraphic sections in the northern and southern portions of the park. This has lead to many problems with the local stratigraphic nomenclature.

THE CHINLE FORMATION

The Chinle Formation in the park is approximately 300m in thickness and comprises of the following units from oldest to youngest, Mesa Redondo, Blue Mesa, Sonsela, Petrified Forest, and Owl Rock Members (Woody, 2003, see Heckert and Lucas (2002) for a different nomenclature). In the park the three medial members are highly fossiliferous; however, the exposures of the Mesa Redondo and Owl Rock Members in the park are minimal and often difficult to access, though they are although known to be fossiliferous elsewhere on the Colorado Plateau (Kirby, 1989; Heckert and Lucas, 2003).

Traditionally, only two members of the Chinle Formation have been considered to be present in the park, the Petrified Forest Member (consisting of upper and lower portions divided by the "Sonsela Sandstone Bed") and the Owl Rock Member (Billingsley, 1985). Independent work by Heckert and Lucas (2002) and Woody (2003; in press) has determined that a distinct lithological change occurs meters below and includes the traditional "Sonsela Sandstone Bed". This distinct lithologic package has been named the Sonsela Member by both sets of workers. Furthermore, both parties have divided the Sonsela Member into the Rainbow Forest, Jim Camp Wash, and Flattops One (=Agate Bridge) beds. Heckert and Lucas (2002) formalized these names, while Woody (2003; in press) urges for continued informal usage. Because these beds are not identifiable outside of the park, an informal usage is preferred for this paper. The Petrified Forest Member is now restricted to the beds between the top of the Sonsela Member and beneath the Owl Rock Member (i.e. the old "upper" Petrified Forest Member). The remnant of the "lower" Petrified Forest Member that is not now part of the Sonsela Member has been assigned to the Blue Mesa Member by Woody (2003; in press). It should be noted that Woody's Blue Mesa Member is a more restricted unit than Lucas' (1993) "Blue Mesa Member" of his Petrified Forest Formation, which contains much of Heckert and Lucas' (2002) Sonsela Member.

Both Dubiel et al. (1999) and Therrien et al. (1999) recognized outcrops of the Shinarump Member and the "mottled strata" (Stewart, 1972) in the Tepees area of the park, but this has been contested by Heckert and Lucas (1998) who argue that these strata instead represent the Mesa Redondo (Bluewater Creek in their usage) Member. The exposures in the park are difficult to interpret yet, exposures in the Tepees clearly show that the coarse sandstone bed interpreted by Dubiel et al. (1999) and Therrien et al. (1999) as the "Shinarump" grades laterally into basal mudstones of the Blue Mesa Member. . Whereas, the dark red, micaceous, muddy sandstone unit underlies both the sandstone and the Blue Mesa Member and most likely represents the Mesa Redondo Member. This assignments is supported by better exposures west of the park near the confluence of Dry Wash and the Puerco River, and also near the I-40-SR77 intersection east of Holbrook. Therefore Heckert and Lucas

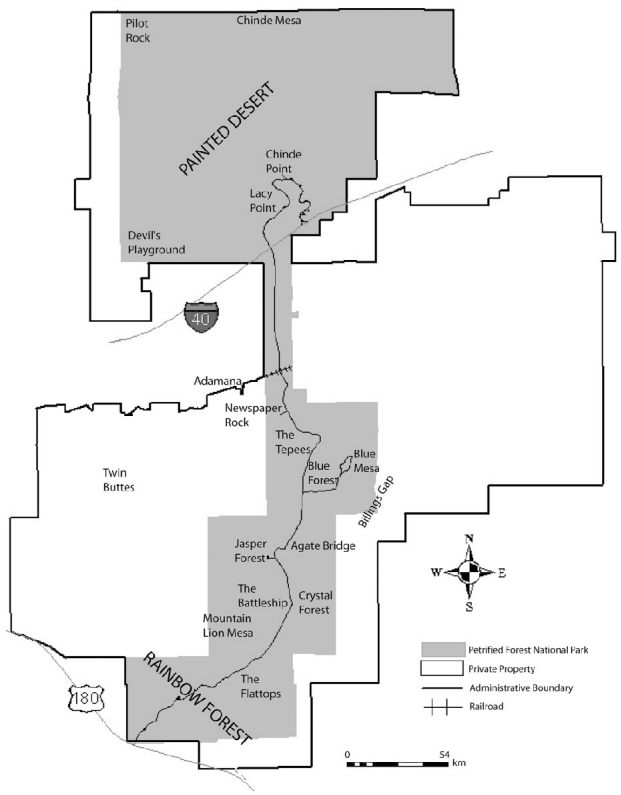

FIGURE 1. Map of Petrified Forest National Park showing current holdings as well as the new administrative boundary of 2004.

(1998) are most likely correct in their assessment that the mottled strata and Shinarump Member are not present within the current park boundaries and that the Mesa Redondo Member is present.

AGE

The only Chinle Formation unit in the park that has been dated is the Black Forest Bed of Ash (1992), which is situated in the medial portion of the Petrified Forest Member approximately 45m above the top of the Sonsela Member and 60m below the Owl Rock Member (Heckert and Lucas, 2002). The Black Forest Bed is a tuffaceous sandstone and mudrock unit that has provided a maximum isotopic date of 213 ± 1.7 Ma from detrital zircons although the authors prefer a date closer to 213 Ma, placing the bed in the late Norian (Riggs et al., 2003). Biostratigraphic data from palynomorphs suggest a Norian age for the Owl Rock, Petrified Forest, and upper Sonsela Members and a Carnian age for the lower Sonsela, Blue Mesa, and Mesa Redondo Members. The "Sonsela Sandstone" palynological sample (R4341) of Litwin et al. (1991) is from the Rainbow Forest bed and provides a Carnian date for this stratum, not Norian as argued by some workers (e.g., Heckert and Lucas, 2002), while samples from the Jim Camp Wash beds (e.g., R4359) provide a Norian date. Thus, the Carnian-Norian boundary is located within the Sonsela Member, not at the base of it (Woody, 2003; 2004; *contra* Heckert and Lucas, 2002 and numerous references by these authors).

Vertebrates have also often been used to assign relative ages to these strata. Numerous papers by staff from the New Mexico Museum of Natural History (e. g., Lucas and Hunt, 1993) divide the late Triassic into "land vertebrate faunachrons (LVF)" based on several index taxa, mostly aetosaurs and phytosaurs. The Adamanian LVF (late Carnian) is based upon the occurrences of the phytosaur *Leptosuchus* (=*Rutiodon*) and the aetosaur *Stagonolepis*, while the Revueltian LVF (early-mid Norian) is based upon the phytosaur *Pseudopalatus* and the aetosaur *Typothorax*. However, research throughout the southwestern United States, including Petrified Forest National Park has shown that the stratigraphic ranges of these taxa overlap, thus negating their biostratigraphic utility (Lehman and Chatterjee 2005; Woody and Parker, 2004; Hunt and Lucas, 2005).

FAUNA AND FLORA

Daugherty (1941) and Ash (e.g., 1966; 1972; 1985; 2001) have provided exhaustive documentation of the fossil flora of Petrified Forest National Park in numerous publications over that last few decades. In addition, Ash described insect-plant interactions (Ash, 1999; 2000), tree ring interpretations (Ash and Creber, 1992), palynomorphs (Litwin et al., 1991) and reconstructions of the trees *Araucarioxylon* (Ash and Creber, 2000), *Woodworthia,* and *Schilderia* (Creber and Ash, 2004). Appendix 1 provides a plant faunal list for PEFO. Also see Ash, this volume.

Good (1993; 1998) has provided the only comprehensive study of park fossil invertebrates, particularly the bivalves and gastropods. Miller and Ash (1998) described a new Triassic decapod from the Tepees area and Walker (1938), Caster (1944), Hasiotis and Dubiel (1995), and Hasiotis et al. (1998) documented numerous invertebrate ichnofossils. Appendix 2 provides an invertebrate faunal list for PEFO.

Camp (1930) published a detailed study of the North American phytosaurs focusing on specimens collected from within PEFO and surrounding area. The vertebrate fauna of the park has been detailed by Colbert (1985), Long and Padian (1986), Murry and Long (1989), and Long and Murry (1995). Appendix 3 provides a vertebrate faunal list for PEFO.

Recently the park has undertaken an intense field survey of historic paleontological localities, which has resulted in the discovery of many new localities and numerous scientifically relevant specimens (Parker, 2002; Parker and Clements, 2004; Stocker et al., 2004; Parker et al., 2005; Parker and Irmis, in press).

ROAD LOG

This road log starts from the south entrance of the park from U. S. Route 180. From Holbrook, Arizona it is 19.3 miles to the turnoff into the park. Just outside of the park entrance are two commercial enterprises that sell souvenirs, petrified wood, and offer information about the park. These facilities are not associated with the National Park Service and are not part of Petrified Forest National Park. Distances are in miles.

0.0 Park Entrance.

0.6 Fee Booth.

1.5 Cottonwood Wash. The cliffs to the north are capped by the Flattops One bed of the Sonsela Member (Chinle Formation). The underlying variegated mudstones and sandstones represent the Jim Camp Wash beds of the Sonsela Member.

1.8 Old Highway 260 (part of the National Old Trails Highway). This section of road is now closed to public travel. The eastern portion winds through conglomeritic sandstones of the Rainbow Forest bed (basal portion of the Sonsela Member), climbing upwards through the Jim Camp Wash beds and the Flattops One bed before exiting the park. In 2004 park staff excavated a partial skeleton of the aetosaur *Stagonolepis* from the Jim Camp Wash beds in this area. The occurrence represents the highest stratigraphic occurrence of *Stagonolepis* in PEFO.

2.1 Outcrops of the Rainbow Forest Bed with fossil logs.

2.2 STOP #1: Rainbow Forest Museum and Historical District. The area was the original park headquarters from the 1920s until the Painted Desert Visitor Center was built to the north along Interstate 40 in the early 1960s. The stone buildings were built by the Civilian Conservation Corps (CCC) in the 1920s and 1930s. This area was the main contact station for park visitors and where information regarding the park was presented. (Fig. 2a,b).

FIGURE 2a. 1947 SVP field trip participants on the front steps of the Rainbow Forest Museum. R-L: Joe Gregory; Halka Pattison; Anne. Simpson; George Simpson; Tom Ierardi; unknown; Ruth Romer; Al Romer. E. H. Colbert photograph, courtesy of the AMNH.

FIGURE 2b. 1947 SVP field trip participants viewing reels of National Park Service films at the Rainbow Forest Museum. Ned Colbert and Al Romer are sitting on the floor just below the center of the photograph. G. G. Simpson is leaning against the back wall in the right margin of the photo. T. Nichols photograph, courtesy of the UCMP.

The original headquarters building is now a museum, which contains displays on Late Triassic paleontology. The other stone buildings serve as offices and residences for park staff. The Fred Harvey building (originally the Rainbow Forest Lodge) was built in the 1920s by local cowboy and entrepreneur Homer "Uncle Dick" Grigsby. Grigsby was interested in the local fossil fauna and flora and often "donated" interesting items to

FIGURE 3. 1947 SVP field trip participants camping in the Rainbow Forest. The Rainbow Forest Museum is visible in the background. T. Nichols photograph, courtesy of the UCMP.

Charles Camp and UCMP paleobotanist Lyman Daugherty, resulting in at least one plant being named in his honor. Camp visited Grigsby regularly during his field seasons in Arizona and New Mexico. During the 1940s and 1950s a campground and picnic area was situated here. It was used by members of the 1947 SVP field trip (Fig. 3).

Behind the Rainbow Forest Museum is a trail through the petrified wood deposit known as Giant Logs. The centerpiece of Giant Logs is a large specimen, with a basal circumference of almost 3 meters (Ash and Creber, 2000), christened by the wife of the first superintendent as "Old Faithful". The Old Faithful log has been the subject of countless photographs (Figs. 4a, b) and at 2:05 pm on June 29, 1962 was struck by a bolt of lightning causing heavy damage (NPS naturalist reports, 1962). Park staff decided to reconstruct the log and added concrete and a base for support. All of the logs in the southern end of the park have been assigned to a single taxon, *Araucarioxylon arizonicum*.

FIGURE 4a. Clyde Polacca examining the "Old Faithful" log in the Rainbow Forest (Giant Logs) in 1923. C. L. Camp photograph, courtesy of the UCMP.

FIGURE 4b. Modern photo of the "Old Faithful" log showing concrete reinforcement and repair. M. Post photograph (National Park Service).

FIGURE 5a. 1890 photograph of logs in the Rainbow Forest (Long Logs). Ben Wittick photograph. (National Park Service)

FIGURE 5b. 2002 re-shoot of the same photograph showing little change in the logs. T. Scott Williams photograph (National Park Service).

2.3 Jim Camp Wash/ Long Logs. Another trail here winds through another petrified forest known as Long Logs. The Giant and Long Logs areas are collectively known as the Rainbow Forest, representing one of the largest accumulations of petrified wood in the world. The logs weather from the Sonsela Member, many from the basal Rainbow Forest bed. Recent comparisons of petrified logs from Long Logs using photos from the 1890s has shown that while little if any erosion of the logs has occurred, the mudstone hills in the background have weathered at least a meter since that time (Figs. 5a, b). The longest log measured from this area is over 40 meters in length and probably was approximately 129 meters in height when alive (Ash and Creber, 2000).

2.8 Upper tongue of the Rainbow Forest bed. This ledge forming, laterally persistent sandstone unit caps the buttes to the right (south) of the road and forms a robust stratigraphic

marker bed for this area, interfingering with the mudstones and minor sandstones of the Jim Camp Wash beds. Murry (1990) considered this unit to represent the traditional Sonsela Sandstone bed.

3.2 Silcrete. The reddish material capping the small hills to the left of the road represents a thin silcrete bed. Woody (2003) states that this unit is always found within 7-9 meters above the main Rainbow Forest bed and forms a useful stratigraphic marker because it is widespread throughout the region. Creber and Ash (1990) attributed this layer to widespread fungal attack on tree trunks. Indeed, examination of this layer demonstrates that is mainly consists of fossil wood, and at several localities flattened tree trunks are discernable in this horizon. Creber and Ash (1990) note a siliceous horizon at a similar stratigraphic level in New Mexico and Texas, while Woody (2003) has observed it insouthern Utah near Paria.

3.5 Flattops One bed. The road drives up onto the Flattops One bed (=Flattops Sandstone One of Billingsley, 1985) at this point.

3.9 Unconformity. These dark brown deposits along the road may be part of the Miocene-Pliocene age Bidahochi Formation or possibly even younger, resulting in an uncomformity of more than 195 million years.

4.3 STOP #2: Turnout. This turnout offers excellent views of the Sonsela and Petrified Forest Members of the Chinle Formation. The Flattops (northeast) and Red Butte (west) consist of reddish mudstone and thin intermittent sandstone ribbons of the Petrified Forest Member.

4.6 Ridge and Swale Topography. To the left and below the road bed can be seen excellent exposures of "ridge and swale" topography in the Flattops One bed. These have been interpreted as representing preserved scroll bars.

5.2 Flattops sandstone beds. These exposures of the Petrified Forest Member are characterized by the presence of several ribbon sandstones that Billingsley (1985) termed Flattops Sandstones Two through Four. The road is situated on the second sandstone, whereas Flattops Sandstone Four caps the buttes in the vicinity. Fossil mollusk beds are common in the mudstones between these sandstones, as are the remains of vertebrates. The phytosaur *Pseudopalatus* and the aetosaur *Typothorax* are the most commonly recovered vertebrates from this unit.

6.2 Dry Wash. The road now proceeds downsection passing back through exposures of the Sonsela Member. Dry Wash is floored by sandstone of the Rainbow Forest bed. Well-developed paleosol horizons can be observed beneath an intraformational conglomerate of the Jim Camp Wash beds in the butte across the road.

FIGURE 6a. 1947 SVP field trip participants examining "Walker's Stump" in the Flattops. J. T. Gregory at left. E. H. Colbert photograph, courtesy of the AMNH.

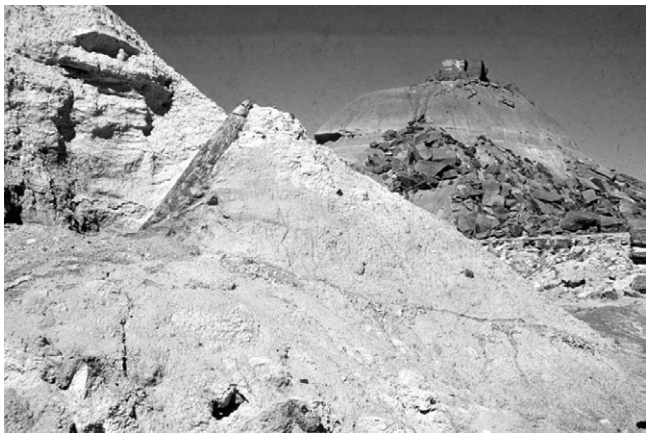

FIGURE 6b. "Walker's Stump" with "Martha's Butte" in background, 1946. E. H. Colbert photograph, courtesy of the AMNH.

6.5 Walkers Stump. In 1935, park naturalist Myrl V. Walker excavated a standing "stump" in a low gray hill next to the prominent "Martha's Butte" northwest of the road. In 1947, the SVP fieldtrip stopped at this site (Fig. 6a,b). Amazingly, the participants drove their vehicles directly to the site, something that is impossible today because of more stringent protective regulations initiated by the NPS.

8.1 STOP #3: Crystal Forest. This short trail passes through another large petrified wood deposit called the Crystal Forest. Here, as in the Rainbow Forest, the logs are found in the basal Rainbow Forest Bed and are also found at various intervals in the Jim Camp Wash Beds. The cobble/gravel clasts strewn across the area are extraformational clasts of Paleozoic age that paleocurrent data suggests derives from a source to the south (Woody, 2003). The majority of clasts are golfball in size, suggesting a very distant source and/or a relatively moderate energy deposition system.

The cliff to the west of Crystal Forest represents the traditional "Sonsela Sandstone Bed" which is now assigned to the Flattops One bed of the Sonsela Member (Heckert and Lucas, 2002; Woody, 2003). In 1982, in the mudstone buttes south of this cliff, crews from the Field Museum and the UCMP excavated the most complete skeleton of the aetosaur *Paratypothorax* (PEFO 3004) from the southwest United States (Hunt and Lucas, 1992).

The large butte across the road from Crystal Forest is called the "Battleship" because log sections sticking out of the sides are reminiscent of cannons.

9.4 STOP #4: Detour (not included in mileage count). Battleship NW locality. This dirt road is not accessible to the public. The cliffs to the north on either side of the road are the Flattops One bed.

The Battleship NW locality (PFV 169) is located in a sandy mudstone facies of the Rainbow Forest bed just lateral to a cross-bedded sandstone that is more typical of the unit. Small extraformational clasts and petrified roots are common here. In 2001, a skeleton of the aetosaur *Stagonolepis wellesi* was collected here, followed in 2004 by a skull of the phytosaur *Leptosuchus adamanensis*.

In 2005, this locality was systematically excavated to determine the presence of any other specimens. The facies here most likely represents a proximal floodplain facies that has been pedogenically modified. Associated skeletons are rare in the Chile Formation, which makes this site significant; however since the bonebed is situated only centimeters below the surface, the bones are weathered before they are subaerially exposed.

The tall butte just west of this site is capped by the same silcrete layer as found at **3.2**.

9.9 STOP #4: Jasper Forest Road. The current road leads to an overlook on top of the Flattops One bed that looks over another substantial petrified wood site. Fossil

FIGURE 7. 1947 SVP field trip caravan parked on the old lower Jasper Forest road. E. H. Colbert photograph, courtesy of the AMNH.

FIGURE 8. Clyde Polacca standing next to the "Eagle's Nest" in 1923. C. L. Camp photograph, courtesy of the UCMP.

vertebrates have also been collected from sites in this valley. The original road was situated slightly north of the current road, accessed the valley floor, and was used during the 1947 field trip (Fig. 7). Eagles Nest Rock was a commonly photographed landmark in the Jasper Forest area (Fig. 8) until it collapsed on January 25, 1941 (NPS Naturalist reports, 1941).

This overlook provides an excellent view of the 'Point of Bluff' area. The bluish badlands at the cliff base represent the Blue Mesa Member, which underlies the sandstones and mudstones of the Sonsela Member. Finally the section is capped by the Flattops Sandstone two of the Petrified Forest Member.

11.1 Agate Bridge. Returning to the main park road and continuing north from Jasper Forest, the road rises and starts to cut through sandstone of the Flattops One bed. A small turnout here leads to Agate Bridge. Agate Bridge is a large petrified log spanning a gully in the Flattops One bed. This site has been a major attraction since the late 1800s and has been the subject of numerous photographs (Fig. 9). In the early 19th century, the Santa Fe Railroad added concrete supports to the base of the log to preserve one of its most famous attractions.

11.2 Roadcut in Flattops One bed. Just past Agate Bridge the park road cuts through the Flattops One bed. Note the channel structures preserved in this sandstone in cross-section. Paleocurrents in this unit, and the entire Sonsela Member, are mainly north and northeast in contrast to the rest of the Chinle Formation, which mainly have

FIGURE 9. Agate Bridge. M. Post photograph (National Park Service).

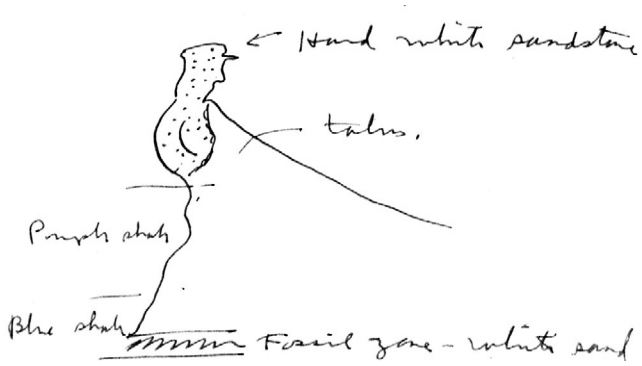

FIGURE 10: Charles Camp sketch of the "Lots Wife" rock formation, 1923. Courtesy of the UCMP.

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northwesterly paleocurrents (Woody, 2003). This strongly suggests a different possible source area and depositional regime for this unit.

12.1 Lot's Wife/King's Throne. The landform to the right of the road is called Lot's Wife. Charles Camp sketched this feature in his 1923 field notes (Fig. 10) and until earlier this year, it had changed little. However, after an abnormally wet spring and a period of high winds in April 2005, the sandstone pinnacle collapsed. The landform to the left of the road is called "King's Throne". The base of both of these features is the Rainbow Forest bed. Woody (2003) traced this bed into the Blue Mesa area to the north where it was informally called the "Camp Butte sandstone" (Murry, 1990).

13.2 Blue Mesa Turnout. Turn right, heading east, to drive up onto Blue Mesa. Blue Mesa is capped by the Flattops One bed (the traditional Sonsela Sandstone Bed), while the flanks are the Jim Camp Wash beds, with the Blue Mesa Member at the base. Blue Mesa is the type section of the Blue Mesa Member (Lucas, 1993); however, this earlier designation included much of what is now considered to be the Sonsela Member (Heckert and Lucas, 2002; Woody, 2003).

15.3 Overlook. Pedestal logs (*Araucarioxylon arizonicum*) in the Flattops One bed. This spot also allows for a distant view of the Dry Creek Tank area where the type specimens of the phytosaurs *Pseudopalatus mccauleyi* (Ballew, 1989) and "*Machaeroprosopus*" *tenuis* (Camp, 1930b) were collected. These sites are on private property originally outside of the park; however both sites fall within the new administrative boundary of 2004.

15.6 STOP #5: Overlook. This spot offers an excellent view of Blue Mesa Member exposures to the north and northwest of Blue Mesa. The "Camp Butte sandstone" (=Rainbow Forest Bed) is well exposed at the base of the cliff and in isolated patches above the Blue Mesa Member mudstones. The "sinking ship" butte to the north consists mainly of the Sonsela Member with a thin capping remnant of Petrified Forest Member. This butte is a syncline thought to be the result of salt-solution collapse of the Supai Formation in the subsurface (Woody, 2003). West of the park, across from the ghost town of Adamana, Ferrell Gas has propane storage in some of these chambers.

Prominent fossil localities in the Blue Mesa Member here include the "Dying Grounds" (PFV 122) as well as Charles Camp's "Crocodile Hill" (PFV 124) and "Phytosaur Basin" (PFV 121). We will visit these sites during this trip.

18.2 Return to Main Park Road. Turn Right.

19.8 STOP #6: Tepees. The turnout here leads to the old Blue Mesa Road. This road originally led to a turnout, picnic area, and trailhead and was closed in the 1950s. In 1947, the SVP field trip caravan drove up this road and parked (Fig. 11). This is not possible today and more conventional methods (e.g., walking) must be used.

The prominent reddish band in the Tepees buttes

FIGURE 11. 1947 SVP field trip caravan parked on the old lower Blue Forest road. E. H. Colbert photograph, courtesy of the AMNH.

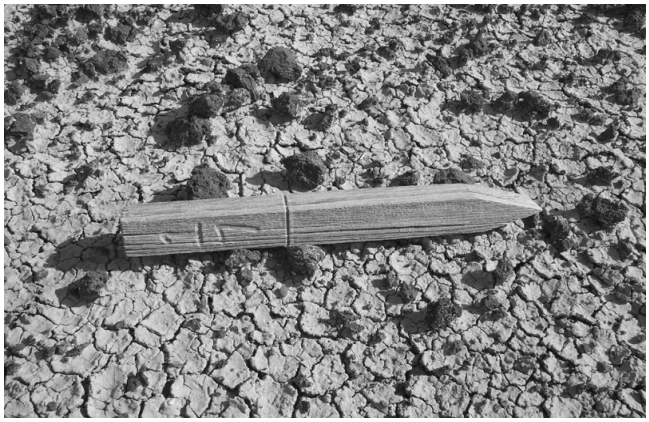

FIGURE 12. E. H. Colbert's erosion measurement stake number "17". B. Parker photograph (National Park Service).

is a pedogenic horizon associated with the Newspaper Sandstone complex. This sequence of sandstones and mudstones is incised into lower Blue Mesa Member deposits and contains a wealth of plant and trace fossils. Interestingly, no vertebrate fossils have ever been recovered from within or below this sequence within the park.

In 1956, Edwin Colbert placed wooden stakes in the mudstones of this area to determine erosional rates in the badlands (Fig.12). Colbert (1956; 1966) determined that approximately 2.5 to 5.7 mm of erosion occurred on these surfaces each year. Many of these stakes are still in place today.

DETOUR: Hiking trip to examine old UCMP localities.

In 1919 Ms. Ynez Mexia, a paleobotanist at the UCMP, arrived in Adamana and inquired where she might find fossils. Directed to the "Blue Forest", Mexia borrowed a horse and briefly prospected this area. A partial phytosaur skull was collected, and while a portion of it was accidentally consumed in a garbage incinerator at the Bright Angel Lodge (Grand Canyon), much of it made it back to Berkeley where it caught the attention of Annie Montegue Alexander (Long and Murry, 1995).

Alexander arrived in Adamana in April, 1921 and briefly prospected the area meeting with some success (Stein, 2001). Encouraged by her finds, she returned in May with her field companion Louise Kellogg, and together from their camp at the head of a prominent arroyo, they heavily prospected the area. The two women also discovered a fossil rich area north of Lithodendron Wash (and present Interstate 40) now known as the "Devil's Playground". Key specimens discovered by Alexander and Kellogg at this time included metoposaur skulls and the type specimens of the phytosaurs "*Machaeroprosopus*" *adamanensis* and "*M*." *lithodendrorum* (Camp, 1930a).

Alexander quickly telegraphed Charles L. Camp, who fresh from his doctorate studies at Columbia University, had recently been hired at the UCMP. Camp joined the women on June 12, 1921 (Camp, 1921) and proceeded to not only collect the women's findings, but to make numerous discoveries of his own. Camp quickly noted that fossils were found in specific horizons and constructed the first vertebrate biostratigraphy for the Chinle Formation (Camp, 1930a; 1930b).

6 mi. S. E. Adamana, Arizona –
Sunday, June 12, 1921
Chas. L. Camp

Stayed last night in small hotel in Adamana. Mr. Nelson, who lives there is custodian of the Petrified Forest Natl. Monument. He gets $12 a year for this and priviledge [sic] of running the auto (lines) to the five various "forests". He is something of an artist and a geologist in a curiously amateurish kind of way. His wife, with the help of a Navajo girl, runs the hotel.

Met Miss Alexander and Miss Kellogg this morning and went back to camp at the "Blue Forest" six mi. S.E. of Adamana. They are working in what H. E. Gregory calls the Chinle Formation and have made some interesting discoveries of what seem to be Phytosaur, Cotylosaur, and Labyrinthodont material similar perhaps to that described by Mehl and Lucas from near Tanner's Crossing. Mehl, at least, got his stuff from the same formation at Tanner's that we are working in here.

The Chinle Formation here is subject to erosion of the typical badland ("Painted desert" type). It's composed of many thin layers of grayish, bluish, purplish, + reddish muddy shale which rapidly disintegrates at the surface. What bone fragments there are – and they do not seem to be numerous – sink rapidly into the muddy surface at times of heavy rainfall.

Adamana, Arizona – Monday, June 13.

Out prospecting through the Chinle this morning. I am calling everything in this area Chinle – this formation consists of several hundred feet of layers and lenses of vari-colored shales and thin occasional layers of gravelly sandstone. All the vertebrate remains I have seen have been in a horizon only a few feet thick just underlying the lowest of the distinctly purplish layers. This horizon consists of an upper layer of gravelly sandstone almost 2 ft. thick and below it a layer of grey-blue shale about 10-12 ft thick.

The most frequent surface fragments seen are fragments of the sternal and clavicular plates of stegocephalians. Phytosaur teeth are quite common, also fragments of phytosaur vertebrae.

Miss Alexander has shown us a few parts of skeletons in situ but the material is very fragile and will require care in excavation. Also there appears to have been considerable dissociation before petrifaction occurred, and consequently many isolated bones.

Hike:

1) *Old Blue Mesa Road*. This road leads back into the badlands below Blue Mesa, an area known as the Blue Forest. This road was built by the NPS to provide access to a trailhead and for a scenic picnic area and was in disuse by the 1970s. A predecessor of this road may have been present in 1921 (based on the 1912 topographic map); however the main park road was not constructed until the 1930s. Three canyons provide access into the badlands, we will proceed up the first (left-most).
2) *1921 Campsite*. On this spot Alexander and Kellogg constructed their camp, which was later inhabited by Charles Camp (Fig.13a,b).
3) *First Canyon*. Robert Long named this canyon, Annie's Canyon, for Annie Alexander. The type locality of "*Machaeroprosopus*" (=*Leptosuchus*) *adamanensis* (Camp, 1930) is located at the top of the arroyo approximately .1 km east of the 1921 campsite (Fig. 14):

Friday, June 17, 1921
Near Adamana, Ariz
Chas. L. Camp
Started work on the bed of bones discovered by Miss Kellogg in the steep bank about 50 feet above the arroyo that runs thru camp. Worked in a short distance over the soft bone + uncovered the back part of the lower jaws of a Phytosaur – apparently a very long jawed form. Worked here all day in teeth of a biting wind blowing gravel in our faces. We could only proceed slowly as the bones are very soft + show tendency to check as soon as exposed to the weather.

4) *Tree stump*. This is a rare example of an in-situ tree stump in the Chinle Formation. Only a handful occur throughout the park. This particular stump is of interest because in 1941 an excavation exposed the root system. The base of the stump was then covered with newspaper, burlap, and plaster to protect and stabilize the specimen (1941 NPS Naturalist notes); however, the vision to develop an outdoor, in-situ exhibit on this spot never developed. In 1946, Ned Colbert reported that torrential rains had washed much of the protective material away and that the stump was significantly damaged. This same storm also washed away two metoposaurid skulls that Colbert was planning on collecting, prompting his interest in Chinle erosion (Colbert, 1956, 1966). In fact, one of Colbert's erosional study sites is just over the ridge to the northwest of this site. In 1947, the SVP group visited this site (Fig. 15).
5) *Crocodile Hill*. In 1923, Camp returned to this area and having little success, determined that success could be met by "digging in". By skill or pure luck,

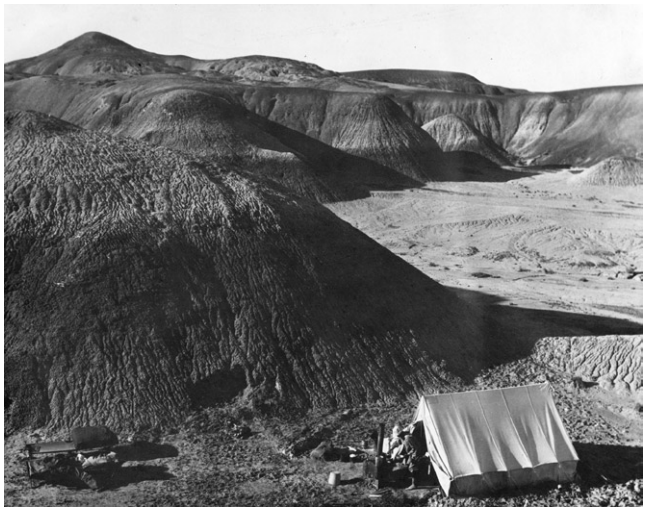

FIGURE 13a. Annie Alexander's 1921 campsite in the Blue Forest. C. L. Camp photograph, courtesy of the UCMP.

FIGURE 13b. Annie Alexander's 1921 campsite in the Blue Forest during a torrential downpour. A. M. Alexander photograph, courtesy of the UCMP.

FIGURE 14. E. L. Furlong standing in the excavation pit for the holotype of the phytosaur "*Machaeroprosopus*" *adamanensis* in 1921. C. L. Camp photograph, courtesy of the UCMP.

the first place he chose was extremely productive:

> April 29, 1923 – Visited the old collecting grounds at Blue Forest. Looked over old diggings + decided that good specimens here would be got by digging alone. Started in to prospect on East facing hillside near where Amphibian Plate was taken 2 yrs. ago + just north (300 = 400 ft) of where Miss Kellogg got her Amphibian Skull.
> Found a complete Phytosaur ilium + other parts of pelvis (partly in place in the Blue Shale just about six inches below the purple beds.
> Dug some more in afternoon and found parts of Amphibian plate
> Locality 31 Phytosaur pelvis + other bones - Blue Forest – N.E. basin - side of "Crocodile Hill" in Blue Shale six inches below the purple beds.

This work continued through May 26th, with over 70 specimens, mainly metoposaurid clavicular and skull elements being collected (Camp, 1923). However, several partial skulls of phytosaurs were also recovered as well as the partial skull of a small reptile (?) that Long and Murry (1995) designated the type of *Acallosuchus rectori*. Camp's notes (1923) describe this specimen as an almost complete small skull of either a dinosaur or a pterosaur; however, when Long rediscovered the specimen in the 1980s it consisted only of fragments (Long and Murry (1995). Little is known about this taxon except that the elongate lower jaw is covered with what Long and Murry (1995) interpret as fused osteoderms. Besides *Acallosuchus*, the "Crocodile Hill" fauna consists of the chondrichthyans "*Xenacanthus*" *moorei* and *Lonchidon* (=*Lissodus*) *humblei*; the lungfish *Arganodus*; the metoposaurids *Buettneria perfecta* and *Apachesaurus gregorii*; the stagonolepidid *Stagonolepis wellesi*; the phytosaurian *Leptosuchus adamanensis*, and the therapsid *Placerias hesternus*. In addition, this site is believed to be the type locality of the aberrant diapsid *Vancleavea campi* (Long and Murry, 1995).

FIGURE 15. 1947 SVP field trip participants listening to park naturalist L. F. Keller discuss a fossil stump in the Blue Forest. E. H. Colbert photograph, courtesy of the AMNH.

Interestingly Camp experimented at this locality with overburden removal using horses and scraper (Fig.16a,b). This technique was also later used at the Canjilon Quarry in New Mexico:

> May 3, 1923
> The stratification is practically horizontal on top of the Blue Forest uplift. I think some doming has occurred but we are working on top of the dome. Dessection has cut thru the fossil layer in many places exposing much fragmentary bone on the surface. The greater part of these fragments are not worth picking up. It will pay us I believe to have some hilltop lying close to the fossil layer leveled off with horse and scraper to allow us to get down to the fossil bed over a greater area than practicable with pick and shovel. The work goes slower than we would wish owing to the difficulties of digging.
>
> May 13, 1923 - Went out to Quarry with R.R. Alton to see about prospects of working off the top of the "Crocodile Hill" at the Quarry. We dug for a few minutes in Loc. 31/4 + unearthed three Amphibian plates including a good interclavicle. Also got a number of teeth.
> Alton says he thinks he can level off the hill for us with a specially improvised plow. We are into the hill so far now that it is difficult to proceed with pick and shovel. We have uncovered about 900 sq. feet of the bone layer and have take out

FIGURE 16a. Initial excavations at the Crocodile Hill quarry, 1923. C. L. Camp photograph, courtesy of the UCMP.

FIGURE 16b. Removal of overburden at the Crocodile Hill Quarry using horses and scraper, 1923. C. L. Camp photograph, courtesy of the UCMP.

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approx. 50 specimens. About one good specimen to each 18 sq.ft. uncovered. Not a high average due to fact that bone is not uniformly distributed but occurs in spots where several good specimens may be close together.

May 15, 1923 – Went out to Quarry with R. R. Alton and Mr. Frank Owenby, horses plow and scraper to try and get some of the loose dirt removed from Crocodile. Worked hard all day and got stuck in the mud in the Puerco Wash in the evening and were compelled to leave car in that place overnight. We will be able to continue work in the quarry for a while but the core of the hill is too hard to plow.

6) *Dying Grounds*. Camp visited this area briefly in 1923, calling it the "amphibian basin". This locality has been extensively screened from microvertebrates (Murry and Long, 1989; Heckert, 2004). In-situ and whole elements are extremely rare at this locality with the majority of the fossils being coprolites, phytosaur teeth, and metoposaurid plate fragments. The productive horizon is difficult to pinpoint and this site is only of interest due to the accumulation of fragments and the microvertebrate potential. Microvertebrates from this locality include "*Xenacanthus*" *moorei*, *Buettneria perfecta*, a possible sphenodont, the archosauromorphs *Trilophosaurus buettneri* and *Crosbysaurus harrisae*, indeterminate osteichthyans, archosauriforms, phytosaurs, aetosaurs, and "rauisuchians" (Heckert, 2004).

7) Return to vehicles up second canyon and back out the old road.

20.4 Roadcuts through Newspaper Sandstone Complex. In 1932, while clearing the roadbed for the main park road, workers stumbled upon a huge deposit of fossil leaves (Ash, 1974) in a greenish mudstone layer associated with the Newspaper Rock Sandstone. These fossils were the basis for a study by Daugherty (1941), whereas this laterally extensive horizon has proven to be extremely productive not only for plant material (Ash, this volume) but for invertebrates as well, including a perfectly preserved decapod (Ash, 1972; Miller and Ash, 1988). The Newspaper Rock Complex also includes the aforementioned red paleosol horizon, as well as beds of ripple-laminated sandstone ranging in thickness from a few millimeters to tens of meters (Demko, 1995). These deposits fill an incised paleovalley in older Blue Mesa Member sediments (Demko, 1995; Dubiel et al., 1999).

20.9 Scrollbars in Newspaper Sandstone. These exposures to the right of the road represent just one of the facies (channel fill/lateral accretion deposits of Demko, 1995) prominent in the Newspaper Sandstone Complex. Demko (1995) interpreted this facies as being deposited by point bar migration and channel aggradation in a high-sinuosity stream.

22.1 Newspaper Rock turnout. This road proceeds to an overlook that allows observation of a large petroglyph panel that gives the Newspaper Rock sandstone its name. The Newspaper Sandstone is 10 meters thick at this point and consist mainly of large scale trough cross-beds capped by small scale trough cross-beds and climbing ripple laminae (Demko, 1995). Although we will not be stopping here today, the 1947 field trip did visit Newspaper Rock back when the trail directly accessing the petroglyphs was still open (Fig. 17a,b).

23.1 Puerco Pueblo. This archaeological site has the unfortunate fate of being named after the nearby Puerco (Spanish for "pig" or "muddy") River. Puerco Pueblo is the remains of a 120 room structure inhabited between 1250 to 1350 (Pueblo IV period). Charles Camp visited this site

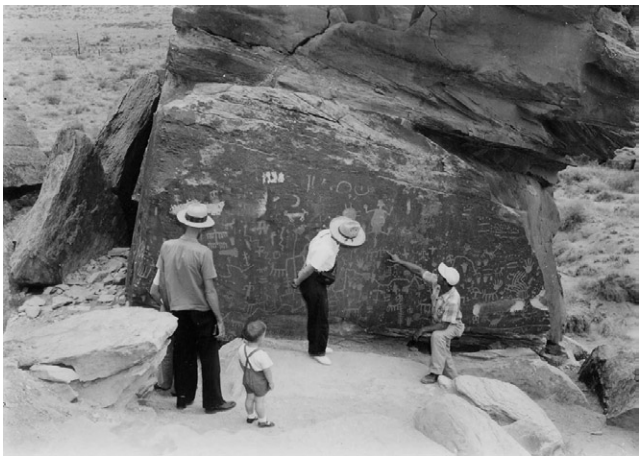

FIGURE 17a. T. Ierardi and others at Newspaper Rock, 1947. E. H. Colbert photograph, courtesy of the AMNH.

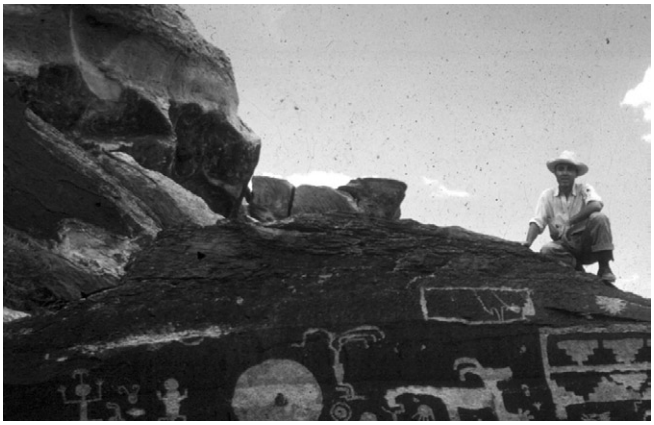

FIGURE 17b. E. H. Colbert posing with petroglyphs near Newspaper Rock, 1946 or 1947. E. H. Colbert photograph (photographer unknown), courtesy of the AMNH

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in 1921, briefly describing the remnant architecture and associated petroglyphs.

Friday June 24, 1921

Near Adamana, Ariz.
Chas. L. Camp

Went out to Locality 12 – 1 mi. East this morning and had scarcely arrived when heard voice calling from ridge near camp and shots fired rapidly in succession – It turned out to be Mr. and Mrs. Lawless and party from Sierra Madre with water and other things for me. I accompanied them to the first forest and the natural bridge then back to Adamana (Figure 18). Here I left them and went toward camp thru the Indian Ruins and by Pictograph cliff.

The ruins are located ½ miles south of the R.R. about 2 mi. E. of Adamana. They cover an area about 200 feet square and that space had evidently been completely surrounded with store houses with a few dwellings in the center of the square. Each "house" or room was very small, 10X12 being an average perhaps, and had been evidently sunk 2-3 feet below the present surface of the earth (tho some wind-drifted sand has blown into the place since.) There are a few fragments of pottery lying about. The rocks have been laid up accurately and with care in some places they have been mortared with baked clay.

I was quite interested in seeing a rock-dam evidently built by these Indians across a mesa wash about 400 yds. S.W. of the ruins. There seems to be no available water now and the climate must have been wetter when the indians lived here.

Pictographs are numerous both on the small cliff (mesa-edge) just south of the ruins and on the great cliff along the high mesa to the south at this latter place there are perhaps a hundred different "sets" of pictures. I saw what seemed to be coyote, elk, antelope, centipede, fox-tracks, plan of house (checkerboard), snake, bird-tracks etc. The famous one of the heron holding the frog in its bill is just to the S. of the ruins. Far in the deep fissures and crevices of the limestone cliff one mile S. of the ruin there are interesting pictures. The Indians must have used these deep + intricate passages – perhaps as refuges. In one place a line of fox-tracks was drown on the rock and following this line into the fissures I actually found sign of foxes perhaps living just as they had lived during the time of the indians. While in a very few instances the pictures seem to be grouped to tell a store (i.e. what a man has seen on a journey) in the majority of cases isolated pictures (representations of animals for the most part) can have no meaning but an artistic desire to put a picture of a well known beast on a rock. There would be found a good deal of natural-history in these pictures if one had the time to study it out.

23.2 Puerco River overpass.

23.7 Santa Fe Railroad overpass/Adamana. About one and a half miles to the east are the remnants of the railroad stop of Adamana, which before the advent of paved highways was the main hub for tourists to the Petrified Forest. John Muir lived here briefly in 1905-1906 and this was the base of operations for Charles Camp as well during the 1921 and 1923 field seasons (Fig. 18). The burning of the Forest Hotel in the 1970s was the death knoll for this town, which currently consists of only three standing buildings and a total of two inhabitants. The town of Adamana should not be confused with the gas storage facility across the railroad tracks from the town site. Note: Adamana is private property and should not be accessed without permission

FIGURE 18. Robert Alton and his general store at Adamana, Arizona around 1923. C. L. Camp photograph, courtesy of the UCMP.

from the landowners.

28.2 Interstate 40 Overpass

28.4 Route 66. These telephone poles are the remnants of the original Route 66, which was replaced by Interstate 40 in the 1960s. Petrified Forest National Park is the only National Park that contains a portion of Route 66. Get your kicks! The predecessor of Route 66 was the Gallup-Holbrook road, which was used by Charles Camp.

29.4 Lacey Point. This is the first of eight overlooks from the Painted Desert Mesa into the Painted Desert.

29.7 Whipple Point

30.0 STOP #7 - Nizhoni Point. This site offers views of the Devil's Playground to the west and the Dinosaur Hill area to the southwest. The Devil's Playground area was prospected heavily by Charles Camp in the 1920s, Ned Colbert in 1946, and the UCMP in the 1980s. Phytosaur skulls are common in the area, including the holotype of *Machaeroprosopus lithodendrorum* (*Leptosuchus crosbiensis*) and specimens of *Pseudopalatus*. In 2002, a PEFO fieldcrew collected another complete skull of *Leptosuchus* sp. from the area, the first complete phytosaur skull collected from the park in 16 years. A second skull of *Leptosuchus sp.* was collected in 2005. The lighter colored outcrops in the Devil's Playground belong to the Sonsela Member of the Chinle Formation. They are exposed due to a structural fold between those outcrops and where we are standing.

To the southwest past Lacey Point the Petrified Forest Member is exposed along a north facing escarpment. This area includes famous fossil localities such as Lacey Point, Dinosaur Hill, and the Giving Site (Fig. 19), which

FIGURE 19. "Coelophysoid flats" at The Giving Site, 2004. B. Parker photograph (National Park Service).

was discovered in 2004. The Giving Site has produced more dinosaur material than any other site in the southwest except for Ghost Ranch and possibly the Snyder Quarry (Heckert et al, 2003). To date, two partial coelophyoid skeletons, isolated coelophysoid elements, and a partial *Chindesaurus* skeleton have been recovered. In addition, the Giving Site has produced numerous skeletons of the pseudosuchian *Revueltosaurus callenderi* (Figure 20), which was originally believed to represent an ornithischian dinosaur (Parker et al., 2005).

Dinosaur Hill (PFV 40) and Lacey Point (PFV 27) are both quarries discovered in the 1980s by crews from the University of California, Berkeley. Lacey Point is a productive microsite (Murry, 1989) while Dinosaur Hill produced a partial theropod skeleton (Padian, 1986), a partial skeleton of the crocodylomorph *Hesperosuchus* (Parrish, 1991; Sereno and Wild, 1992), numerous *Revueltosaurus* teeth (Padian, 1990), as well as a large amount of amphibian material referable to *Apachesaurus gregorii* (Hunt, 1993).

FIGURE 20. University of Minnesota graduate students at initial discovery of the *Revueltosaurus* Quarry in 2004. B. Parker photograph (National Park Service).

Just north of Dinosaur Hill is the "Billingsley Hill" Locality (PFV 34) where the tooth of an enigmatic amniote was collected in 1984. This specimen was previously believed to represent a traversodontid synapsid (Long and Murry, 1995) but its true affinities are still unclear (Irmis and Parker, in press).

31.2 Pintado Point.

31.8 Turnout to Chinde Point.

32.1 STOP #8 – Chinde Point. This point provides another excellent vista of the Painted Desert. The red mudstones and thin brown sandstones are part of the Petrified Forest Member. The white bed is the volcaniclastic Black Forest Bed, which has been dated using detrital zircons at 213 ± 1.7 Ma. The long mesa that forms the northern horizon (Chinde Mesa) is capped by deposits of the Owl Rock Member. Just below this point to the west of three low lying hills, the UCMP collected the holotype of the controversial dinosaur *Chindesaurus bryansmalli* in July, 1985 (Fig. 21). Erroneously billed as the "world's earliest dinosaur," the block containing the fossil was ceremoniously airlifted by helicopter from this spot to the Painted Desert Inn. The massive media event was accompanied by an elaborate banquet at the Painted Desert Inn for guests and dignitaries. This overlook also provides closer examination of the Bidahochi Formation basalts including some spectacular pillow structures (Fig. 22). These flows are part of the Miocene-Pliocene Bidahochi Formation, which uncomformably overlies the Petrified Forest Member in this region. These basalts are part of a series of maar volcanoes, formed from eruptions in a lacustrine setting.

A short walk brings us to a misplaced block of Moenkopi Formation sandstone containing a skull of the temnospondyl *Eocyclotosaurus*. Given that Moenkopi vertebrates were not easily observed on the earlier portion of the fieldtrip, we will examine this specimen (Fig. 23).

FIGURE 21. *Chindesaurus bryansmalli* holotype locality off of Chinde Point, 2004. B. Parker photograph (National Park Service).

FIGURE 22. Basalts of the Bidahochi Formation at Chinde Point. B. Parker photograph (National Park Service).

This block was brought to the park in the early 1990s and is from the area around the Cholla powerplant just east of Joseph City. It was partially prepared in public view in the PDVC courtyard for a short period, and then removed to this spot. It is unknown why this specimen ended up in the park, what its exact provenance is, or why preparation was never completed, however plans are being made to salvage this specimen.

Back out to main road, **turn left.**

31.9 Kachina Point. This overlook provides an excellent panorama of the Painted Desert portion of the park. The southwestern style building here is the Painted Desert Inn, built in the 1920s and refurbished by the Civilian Conservation Corps (CCC) in the 1930s.

FIGURE 23. *Eocyclotosaurus* skull in Moenkopi Formation block (transported) at Chinde Point. B. Parker photograph (National Park Service).

33.2 Tiponi Point. This is the last of eight overlooks on the Painted Desert Mesa providing scenic views into the Painted Desert. From this vantage point the Petrified Forest Member is visible.

33.4 Route 66. Trending NE-SW the road on the right hand side is old US Route 66. Decommissioned in 1985, Route 66 was once the main thoroughfare from Chicago to Los Angeles carrying over 1 million vehicles each day.

33.7 Painted Desert Visitor Complex. Completed in 1962, this complex was placed in the National Register of Historic Places in 2005. It is one of the only remaining examples of NPS "Mission 66" architecture designed by noted architect Richard Neutra. In 2005 this complex was listed on the National Register of Historic Places. These buildings house the museum collections and fossil preparation facility as well as park administrative offices and personal residences. A restaurant, visitor center, gift shop, and convenience store are also present.

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APPENDIX 1:

Known fossil plants (excluding palynomorphs) from the Chinle Formation of Petrified Forest National Park (Ash, written comm., 2003).

Lycopodiales

*Chinlea campii** (Daugherty) Miller 1968
Chinlea sp.

Equisitales

*Equisetites bradyi** Daugherty 1941
Equisetites spp
*Equicalastrobus chinleana** (Daugherty) Grauvogel-Stamm and Ash 1999
Neocalamites virginiensis (Fontaine) Berry 1912
Neocalamites sp.

Filicales

*Todites fragilis** Daugherty 1941
*Cynepteris lasiophora** Ash 1970
*Phlebopteris smithii** (Daugherty) Arnold 1947
*Clathropteris walkeri** Daugherty 1941
*Cladophlebis daughertyi** Ash 1970
*Cladophlebis yazzia** Ash 1973
Cladophlebis spp.
*Itopsidema vancleaveii** Daugherty 1960
*Wingatea plumosa** (Daugherty) Ash 1970
*Sphenopteris arizonica** Daugherty 1941

Cycadales

*Aricycas paulae** Ash 1991
*Lyssoxylon grigsbyi** Daugherty 1941
*Charmorgia dijolli** Ash 1985

Bennettitales

Zamites powellii Fontaine 1890

Ginkgoales

*Baiera arizonica** Daugherty 1941

Cordaitales

*Dadoxylon chaneyi** Daugherty 1941

Coniferates

*Araucariorhiza joae** Daugherty 1963
*Pagiophyllum simpsonii** Ash 1970
Araucarioxylon arizonicum Knowlton 1888
*Podozamites arizonicus** Daugherty 1941
*Brachyphyllum hegewaldia** Ash 1973
*Samaropsis puerca** Daugherty 1941

Position uncertain

*Carpolithus chinleana** Daugherty 1941
*Pramelreuthia yazzi** Ash and Litwin 1996
*Dinophyton spinosus** Ash 1970
*Schilderia adamanica** Daugherty 1934
*Marcouia neuropteroides** (Daugherty) Ash 1972
*Woodworthia arizonica** Jeffrey 1910

APPENDIX 2:

Invertebrate body and trace fossils described from Petrified Forest National Park. From Good (1998), Walker (1938), Caster (1944), and Hasiotis et al. (1998).

Bivalvia
Unionoidea
Hyriidae
Antediplodon cristonensis (Meek, 1875)
Antediplodon dockumensis (Simpson, 1896)

Antediplodon dumblei (Simpson, 1896)
Antediplodon gallinensis (Meek, 1875)
Antediplodon graciliratus (Simpson, 1896)
Antediplodon terraerubrae (Meek, 1875)
Antediplodon thomasi (Henderson, 1934)
*Antediplodon torrentis** Good, 1993b
*Antediplodon tenuiconchis** Good, 1993b
*Antediplodon acuodorsis** Good, 1993b

Unionidae
Plesielliptio? *altidorsalis** Good, 1998
Plesielliptio? *arizonensis* (Henderson, 1934)
Plesielliptio? *pictodesertis** Good, 1998

Gastropoda
Mesogastropoda
Pleuroceriidae
Lioplacodes assiminoides (Yen, 1951)
Lioplacodes canaliculatus (Yen, 1951)
Lioplacodes latispira (Yen and Reeside, 1946)
Lioplacodes pilsbryi (Yen and Reeside, 1946)
Ampullaridae
Ampullaria gregoryi (Robinson, 1915)

Ichnospecies

*Archeoentomichnus metapolypholeos** Hasiotis and Dubiel 1995 (Social Insect Nests)
*Kouphichinium arizonae** Caster 1944 (Limuloid trails)
*Paleobuprestis maxima** Walker 1938 (insect burrows in wood)
*Paleobuprestis minima** Walker, 1938 (insect burrows in wood)
*Paleoscolytus diverges** Walker, 1938 (insect burrows in wood)
*Paleoipidus perforatus** Walker, 1938 (insect burrows in wood)
*Paleoipidus marginatus** Walker, 1938 (insect burrows in wood)

APPENDIX 3:

Known fossil vertebrates from the Chinle Formation of Petrified Forest National Park. From Murry and Long (1989), Long and Murry (1995), and Heckert (2004).

CHONDRICHTHYES
"*Xenacanthus" moorei* -- BMM
Lonchidion (=*Lissodus*) *humblei* -- BMM
Acrodus sp. - BMM
OSTEICHTHEYES
cf. *Turseodus* – BMM, PFM
Redfieldiids – BMM, PFM
cf. *Lasalichthyes*
Colobodontids -- BMM
Arganodus dorotheae – BMM, PFM
cf. *Chinlea* sp. – BMM, PFM
AMPHIBIA
Metoposauridae
Buettneria perfecta Case, 1922 – BMM, SM, PFM
Apachesaurus gregorii Hunt, 1993 – BMM, SM, PFM
AMNIOTA
Incertae Sedis
*Kraterokheirodon colberti** Irmis and Parker, 2005 - PFM
Diapsida
Archosauromorpha
Trilophosauria
Trilophosauridae
Trilophosaurus buettneri Case, 1928 - BMM
Trilophosaurus sp. - SM
Archosauria
Phytosauridae
*Leptosuchus adamanensis** (Camp,1930) - BMM, SM
Leptosuchus crosbiensis Case, 1922 - SM
*Pseudopalatus pristinus** Mehl, 1928 - SM,, PFM
*Pseudopalatus maccauleyi** Ballew, 1989 - SM, PFM
Stagonolepididae
Stagonolepis wellesi (Long and Ballew, 1985) - BMM, SM
Desmatosuchus haplocerus (Cope,1892) - BMM
Desmatosuchus smalli Parker, 2005 - PFM
Typothorax coccinarum

Cope, 1875 - SM, PFM
Paratypothorax sp. - SM, ?PFM
"*Desmatosuchus" chamaensis* Zeigler, Heckert, and Lucas 2002 - PFM
Acaenasuchus geoffreyi Long and Murry, 1995 - BMM
"Rauisuchia"
Postosuchus kirkpatricki Chatterjee 1985 - BMM, PFM
"*Chatterjeea elegans*" Long and Murry, 1995 → *Shuvosaurus inexpectatus* Chatterjee, 1993 - PFM
Sphenosuchia
Hesperosuchus agilis Colbert, 1952 - BMM, PFM
Parrishia mccreai Long and Murry, 1995 - BMM
Saurischia
*Chindesaurus bryansmalli** Long and Murry, 1995 - PFM
Coelophysis sp. - PFM
Incertae sedis
*Acallosuchus rectori** Long and Murry, 1995 - BMM
*Vancleavea campi** Long and Murry, 1995 -BMM, PFM
Revueltosaurus callenderi Hunt, 1993 - PFM
Crosbysaurus harrisae Heckert, 2004 - BMM

Synapsida
Therapsida
Dicynodontia
Kannemeyeriidae
Placerias hesternus Lucas,1904 -BMM

BMM = Blue Mesa Member
SM = Sonsela Member
PFM = Petrified Forest Member
* The type specimens for these species are from Petrified Forest National Park.